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# SITE CONDITIONS FOR JACK PINE SEEDING

by

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**FORWARD**

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**ABSTRACT**

There is a strong relevance between jack pine (Pinus banksiana Lamb.) regeneration and the combined site and seedbed conditions at the time of seeding. Both unfavourable and favourable seedbed characteristics are reviewed first by groups of sites, and then depending on available seed sources, optional uses of major seedbed and seeding treatments are discussed in order of practical preferences. Site groups with regeneration potential ranging from high to low are also indicated.

## SITE CONDITIONS FOR JACK PINE SEEDING

Practically all jack pine (Pinus banksiana Lamb.) stands that are now harvested owe their existence to forest fires. This is because wild fires burning through the pine stands often expose favourable mineral and organic seedbeds, reduce immediate plant competition, and trigger (by heating) seed dispersal from the otherwise serotinous cones on parent trees above the seedbeds. Abundant pine regeneration nearly always follows such fires, and only when the available seed sources are completely destroyed, as in burning young stands, for example, may the results be disappointing. Generally, however, these favourable regeneration conditions are not met when the timber is harvested, and unless suitable remedial postcut treatments are carried out, the pine usually fails to regenerate in adequate numbers (Cayford et al. 1967). This paper reviews the basic seedbed requirements and then highlights some of the optional regeneration seeding methods that are more or less currently in use.

### SPECIFIC CONDITIONS

#### The Forest Floor

One of the important developments in our northern forests, including the jack pine stands, is the slow decomposition and consequent buildup of organic materials right on top of the mineral soil (Lutz and Chandler 1946; Weetman 1980). The process is maintained by the continuing growth of mosses and/or by the sustained additions of discarded dead foliage and other plant litter, including fractions of woody materials. This results in an organic mat that is thoroughly interwoven with plant roots, forming an integrated part of the forest floor. The accumulated materials are summarily called "raw humus", "mor humus",

or simply "duff", if present on uplands and "peat", if present on lowlands (Chrosciewicz 1978d, 1980). These materials vary in depth with stand age, stand density, stand composition, and site. Their profiles usually show downward increases in both decomposition and bulk density, starting with the unaltered moss and/or the loos, discarded dead foliage and other plant litter on the top, and ending with the fully decomposed, somewhat compacted true humus at the bottom. Most of the materials between these limits are in their fibrous, partly decomposed state, which in moss are permeated with fungal hyphae (Anon. 1978).

Among the main contributors to the buildup of these materials are feather mosses (mainly Pleurozium schreberi [Britt.] Mitt., but also Hylocomium splendens [Hedw.] B.S.G. and Ptilium crista-castrensis [Hedw.] De Not.) occasionally in association with reindeer mosses (Cladina spp.) on some of the poorer dry uplands, and in association with typical peat mosses (Sphagnum spp.) on some of the poorer wet lowlands (Chrosciewicz 1976, 1978d, 1980). However, dead foliage and other plant litter can be the main material on the forest floor if the stands have closed canopies and produce heavy leaf fall, which the feather-moss species in particular cannot tolerate (Place 1955).

**Unfavourable Seedbeds**

Poor seedbed conditions are created by both reindeer and feather mosses. The surface moss structures are generally loose and subject to rapid losses of moisture. When exposed to direct solar radiation as, for example, after harvest cutting, the feather moss in particular dies out, further aggravating the predominantly droughty seedbed conditions (Chrosiewicz 1978d, 1980, 1983b). One exception to this is the seemingly always moist peat moss, which can be a

favourable seedbed medium, especially for black spruce (Picea mariana [Mill.] B.S.P.) (Heinselman 1957; Losee 1961; Chrosciewicz 1976).

Poor seedbed conditions are also created by undisturbed raw humus (Eyre and LeBarron 1944; Baker 1950; Hawley and Smith 1954; Cayford et al. 1967). Consisting mostly of partially decomposed organic debris, which can be of considerable depth and which is always topped with an assortment of newly discarded bits and pieces of twigs, bark, foliage, and other plant litter, the raw humus is a formidable hindrance to jack pine regeneration. The materials form a loose meshwork of large noncapillary interstices that let rainfall through but then retard the upward movement of moisture as the surface strata dry out (Baker 1950). Moreover, the organic materials have low thermal conductivities, and when exposed to direct solar radiation they are subject to excessive surface temperatures (Cochran 1969). Under these conditions the losses of moisture are rapid, and depending on depth, the entire raw humus may dry out in a matter of days after a drenching rain.

## Favourable Seedbeds

Although some disturbance of the forest floor occurs during logging operations, the resulting improvement of seedbeds is usually inadequate, and either mechanical scarification or controlled burning has to be used to rectify the situation. Under the weather and site conditions that prevail on our northern cutovers, the most favourable jack pine seedbeds are mineral soil exposed by scarification or burning (Eyre and LeBarron 1944; Ahlgren 1970; Chrosciewicz 1959, 1960b, 1967, 1970, 1974; Cayford et al. 1967), lower raw humus strata exposed by scarification or burning (Cayford et al. 1967;

Chrosciewicz 1967, 1970, 1974, 1978a, 1987b), and lower peat strata exposed preferably by burning (Chrosciewicz 1976).

When exposed, the mineral soil is universally recognized as the best medium for jack pine regeneration (Eyre and LeBarron 1944; Baker 1950; Haig 1959; Chrosciewicz 1959; 1960b, 1967, 1970, 1974; Jarvis 1966; Cayford et al. 1967; Arnott 1973, Brown 1973). It maintains the upward movement of moisture by capillary action, and the nature of its mineral soil particles is well suited to provide close contacts between the seed and the surface films of the moisture (Baker 1950). As a source of moisture, therefore, the mineral soil is considered much more stable than most organic seedbeds (Smith 1962), which generally lack these important attributes (Baker 1950).

The mineral soil also has a good thermal conductivity (Baker 1950), enabling it to transmit heat downward fast enough to maintain correspondingly lower surface temperatures (Cochran 1969). The moisture contained in the mineral soil also helps to mitigate the surface temperatures both through the cooling effect of evaporation and by increasing thermal conductivity (Geiger 1957). Nevertheless, to mitigate the effects of drought even on the best mineral seedbeds, some degree of shade is essential for good germination and early survival of seeded jack pine. Once the seedlings are firmly established with leaders above the surrounding vegetation, they grow best in full sunlight (Chrosciewicz 1960a).

This is as far as generalities go. The water-holding capacity of mineral soil normally increases with the increasing content of silt plus clay, and this has a positive effect on the establishment of seeded pine, particularly where a substantial portion of the exposed material is sand (Chrosciewicz 1970). In contrast, a nearly pure upland outwash sand may be at times so dry when exposed

that the seeded pine completely fails to regenerate (Chrosciewicz 1983a). However, a texturally identical outwash sand, but in a lowland situation and having a midsummer water table at 0.9 m below the surface, is well suited as a regeneration medium for the seeded pine, even when it is only partially exposed. The favourable seedbed conditions in the latter example are attributed to the presence of a high water table that supplies the soil profile with much of its moisture in addition to the amounts of rainfall received (Chrosciewicz 1983a).

When the generally more compacted lower raw humus strata become exposed as a result of scarification or burning, favourable seedbeds are also created. In fact, on productive upland sites (Hills 1955) with a relatively shallow raw humus, deep mineral profiles, and soil moisture regimes $\leq 3$, the best seedbed conditions are produced where exposed mineral soil and thin residual humus alternate and both have uniform areal distribution (Chrosciewicz 1970, 1974, 1980, 1983b). Deeper raw humus materials and lowland peats (Hills 1955) over deep mineral profiles, with effective high water tables and soil moisture regimes $\geq 4$, become favourable seedbeds almost as soon as the generally loose surface moss and litter materials are burned off or perhaps mechanically removed if at all practical (Chrosciewicz 1976, 1980, 1983a).

In all cases, the quality of seedbeds normally improves with the depth reduction of organic forest-floor materials. This, however, does not mean that complete removal or destruction of such materials is required to produce optimum seedbeds. On the contrary, large quantities of insoluble nutrient compounds are stored in those materials, and although some disturbance is usually needed to make the nutrients more readily available to the plants, a complete removal or destruction of such materials either by scarification or by burning is extremely wasteful and must be avoided. This is particularly critical in dry upland

situations where the mineral soil is nutritionally poor outwash sand or gravel, drains very rapidly, has a very low water-holding capacity, and frost-heaves when exposed. A complete removal or destruction of the organic forest-floor materials can also be harmful if the mineral soil is clay or contains much clay, because then on drying its surface structure breaks down into extremely compacted fractional aggregates that interfere with normal plant rooting. The objects of most silvicultural uses of scarification and burning is therefore not the total removal or destruction of all organic forest-floor materials present, but rather their reduction to a degree sufficient for prompt re-establishment of seeded pine wherever required (Chrosciewicz 1978d).

Perhaps the most important factors affecting the moisture content of seedbeds, and consequently the ultimate success or failure or seeding, are the amount and disturbance of rainfall (Smith 1964). Some seedbeds that are considered favourable under normal rainfall conditions may not be so during periods of drought, and some of those that are usually unfavourable may manifest favourable characteristics in response to prolonged periods of wet weather. In fact, both the deficit and low frequency of rainfall (Chrosciewicz 1983a) as well as the surplus and high frequency of rainfall (Chrosciewicz 1983b) can have profound, though opposite effects on the quality of seedbeds as rated in terms of pine regeneration. Unfortunately, abnormal patterns of rainfall are seldom predictable and so are some of the results of jack pine seeding.

**Available Seed Sources**

Jack pine is reputed to be a prolific producer of seeds. It is not unusual for a well-stocked, mature stand on a good site to yield about 14.5 to 15.1 kg of seeds/ha (Eyre and LeBarron 1944). At that age, the cones containing

these seeds are usually situated high in the crowns. Most of them are serotinous and are just waiting for the heat of the next fire to initiate their opening and subsequent seed dispersal over the fire-improved seedbeds right below the parent trees. The potential for a dependable stand rejuvenation therefore always exists under such conditions. However, when the timber is harvested through clear-cutting, the entire mass of cone-bearing branches is brought down to the ground, where in situ they are subject to cone opening by the heat of solar radiation. In this case, the seeds are released over the unimproved original seedbeds and so, under normal weather conditions, they in time become completely wasted. Only when the branches with cones are lopped and scattered at some spacing over an exposed mineral soil nearby prior to cone opening, can the subsequent release of seeds from the cones result in pine regeneration (Cayford 1958; Chrosciewicz 1971).

Whether in the crowns of parent trees or on branches near the ground in logging slash, jack pine cones require a temperature of at least 50°C for the bonds between their scales to melt and thus start their opening through the forces of desiccation (Cameron 1953). In both locations, the cones are valuable sources of seeds and they should be used as much as possible in our treatment to regenerate the pine after cutting. At this point one must remember that the cones in slash hold their seeds in ever-diminishing numbers for one or perhaps two years, and that their usefulness is practically nil thereafter (Chrosciewicz 1960b). Moreover, one should also know that slash burning alone cannot be regarded as a dependable means of releasing the seeds from cones in that slash, because the fire either destroys the seeds or drastically reduces their viability (Chrosciewicz 1959, 1987b).

To preserve the source of seeds in jack pine slash, full-tree logging with subsequent delimbing of crown elements at some central location should be discouraged. This not only deprives the clear-cut site of a cost-free, readily available seed source for the short-order regeneration treatment, but it also strips the site from a valuable postcut addition of nutrients which should be rightfully returned back to the soil. It is quite possible that the full-tree logging can be more productive and hence more economical than other methods of timber extraction, but eventually someone else has to bear the resulting extra costs of regeneration and perhaps of site amelioration. In short, the logging operation and its consequences should be always compatible with the overall plan for the postcut pine regeneration and its projected development.

## OPTIONAL TREATMENTS

### Mechanical Scarification and Slash Redistribution

Drag scarification of the forest floor with simultaneous redistribution of the cone-bearing slash is one of the most dependable methods of regenerating the pine after clear-cutting. This method takes the full advantage of the ample seed source that is locally available, and if it is used during the summer months after logging, or as soon as the slash becomes sufficiently brittle, good scarification and slash redistribution is achieved.

The object of this type of operation is to produce up to 100% of disturbance with well-distributed patches of exposed mineral soil totalling at least 40-50% in area and having a light cover of cone-bearing branches over them. Reasons for failure of this treatment may include poorly executed scarification and/or insufficient seed availability because of excessively delayed scarification. A shortage of available seeds can also result from full-

tree logging when most of the slash is removed from the site. It is otherwise not unusual to have the clear-cut sites 90-93% stocked[1] to jack pine 5 years after the treatments (Ball 1975).

The drag equipment usually consists of ship anchor chains with double spikes welded into the links. Five 6 m chains are often attached to a 4 m drawbar and pulled either by a wheeled skidder as on dry uplands where less pull is required or by a tracked machine elsewhere where more pull is needed. The recommended weights of drag chains and the size of machinery vary directly with the relative weight of slash and the mean depth of raw humus (Anon. Undated).

### Controlled Burning and Seed-Tree System

Slash burning in conjunction with a seed-tree system is perhaps the most natural, dependable method of regenerating jack pine after cutting. It also takes advantage of the locally available seed source, but in this case seed trees must be marked and left standing while all other timber is harvested. Burning of logging slash here improves the seedbeds and the heat so generated is sufficient to initiate cone opening on the seed trees. The dispersal of seeds by the trees is at first intensive and then later becomes more gradual and usually lasts for up to 3 years after burning. This gives the pine an ample opportunity to regenerate under a variety of weather conditions, including the favourable ones for its establishment.

Generally, there are very few recorded instances of successful jack pine regeneration by this method. Burning under an open stand (Chrosciewicz 1959)

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[1] The stocking values as quoted in this paper are based on sample quadrants of variable size, 4.05 $m^2$ for old surveys and 4.00 $m^2$ for recent surveys.

as well as two other examples of burning under designated seed trees (Ahlgren 1970; Chrosciewicz 1987b) certainly belong to this category, with the pine stocking of 60, 83, and 90% 4 years after burning, respectively. Extensive operational trials with the burning and seed-tree systems are now required to determine their economic feasibility at that level of implementation (Chrosciewicz 1987b).

Means of selecting the proper conditions for burning the desired amounts of raw humus are already available and require only local adaption (Chrosciewicz 1978a, 1978b, 1978c). About 20 seed trees/ha should provide satisfactory postburn seeding (Chrosciewicz 1987b).

### Mechanical Scarification and Direct Seeding

Old cutovers, old burns, and other poorly regenerated areas are often suitable for scarification and direct seeding. In practice, mechanical scarification includes all degrees of mineral soil exposure, from very minimal to extreme. The exposure may be at random with considerable intermixing of organic materials, in parallel strips or furrows, or in uniformly spaced scalps. Among the equipment currently in use are: (a) diverse bulldozer blades, shark-finned drums, and anchor chains for more or less strip and random scarification; (b) ploughs, rippers, and disk trenchers for scarification in furrows; and (c) various spot cultivators for scarification in scalps (Cayford et al. 1967; Hellum 1973; Rudolf 1973; Waldron 1973; Norman 1978; Orynik 1985; Peterson 1985).

Direct seeding may involve spot seeding with special cultivators which automatically release a few seeds on each scarified scalp. It may be done as row seeding with some other devises that space the seeds evenly along the

ploughed furrows. Otherwise, Cyclone seeders may be used where post-scarification broadcast seeding is the objective. This can be done by covering the ground on foot, by snowmobile, or by helicopter, although a fixed-wing aircraft and a Brohm seeder is the better combination.

Because the amount of seed sown and the season of seeding vary considerably from operation to operation, the results are extremely erratic (Hellum 1973; Rudolf 1973; Waldron 1973). However, a direct relationship exists between the pine stocking and the proportion of favourable seedbeds that is available (Riley 1980). A well-distributed mineral soil exposure of 15-25% and an aerial seeding of pine at the rate of 50,000 seeds/ha are usually required for optimum stocking. As the amount of seeds sown increased above 50,000 seeds/ha, stocking does not increase significantly (Smith 1984). Whether on the ground or from the air, all broadcast seeding should be done in early spring either over a fresh snow or before the snow leaves the ground (Brown 1973; Hellum 1973; Smith 1984). If the Bracke is used as a spot scarifier and seeder, the best pine stocking is obtained when the operation takes place during the (presumable snow-free) spring period and when the seeding rate is 15 viable seeds per scarified scalp (Clark 1984).

**Controlled Burning and Direct Seeding**

Whether the burning is conducted with or without presence of seed trees similar weather and fuel conditions are required for the desired improvement of seedbeds. The moisture content of the forest-floor organic materials controls the depth of burn into the raw humus as well as the consequent degree of mineral soil exposure. There are several available regressions between the Duff

Moisture Code (DMC)[2] representing this moisture content and the results of burning for different standardized mean, original preburn humus depths which in turn represent the different sites or groups of sites (Chrosciewicz 1978a, 1978b). Specific guidelines on how to conduct the burns are also available (Chrosciewicz 1978c). All of this material can be used to select the proper DMC and other conditions for the use of burning that would best match the local situation. Summer burning as compared with spring burning is preferable because it produces better results in terms of seedbed improvement (Chrosciewicz 1959, 1967, 1974). The cured logging slash and other dead plant materials are important, mainly in sustaining fire ignition and its spread.

Here again the amount of seed sown, 0.35-2.12 kg/ha (viability 50-80%), varies substantially from operation to operation, often testing the effect of different fire-produced seedbeds by diverse physiographic sites in relation to both constant-single and constant-double seeding rates; these are applied mostly in the spring but with some replications in the fall. A Cyclone seeder is used in practically all of these operations.

On the whole, jack pine regeneration is significantly better after spring seeding than after fall seeding (Chrosciewicz 1987a), and out of 96 spring seeding tests, 12 completely fail because of abnormally droughty weather and soil conditions (Chrosciewicz 1983a), 42 produce 11-60% stocking, and the remaining 42 produce 61-100% stocking (Chrosciewicz 1959, 1970, 1983a, 1983b, 1987a, 1987c). In one instance, a postburn scarification and aerial application of 50,000 seeds/ha results in 80% pine stocking (Smith 1984).

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[2] A component of the Canadian Forest Fire Weather Index System (Anon. 1984).

After so much testing, there is a general feeling and recognition that the burning and seeding treatments should be primarily used on those non-reproducing lowland problem sites where mechanical scarification is either too expensive, too difficult, or simply too messy to even be considered. There is so far not even one instance of failure on such sites, and certainly the burning and seeding treatments are capable of producing well-stocked and fast-growing pine stands. A permanent water table at 0.6-1.5 m below the surface is the common and necessary feature of these sites. Sandy outwash plains, river terraces, and similar other lowland formations regardless of mineral texture belong to this category. The fire-induced exposure of mineral soil on these sites is usually minimal, and the pine germinates and develops well on partially burned humus.

Next in line of priorities are the richer upland sites with silty and loamy sands, sandy loams, loams, glacial tills, etc., within their mineral soil profiles. The total fire-induced exposure of mineral soil on these sites should be about 50% and well alternating in its patch distribution with the residual, partially burned humus. The risks of failure and the chances of a wide variation of results in terms of pine regeneration are much greater here than on the lowlands.

The last category of sites with deep mineral soil profiles under consideration consists of poor-quality sandy uplands, particularly in areas subject to the negative influences of periodic droughts. Neither burning nor seeding treatments, whether singly or in combination, should be conducted on these sites because the possibilities of successful pine regeneration here are extremely small. On sites such as these, one has no other recourse than to

finally apply the Triple-P treatments, which may conceivably mean: plough, plan, and ... pray.

## CONCLUDING COMMENTS

Indications are that with the proper selection of treatable sites and the right treatment prescriptions best fitting the local conditions, both the risks of failure and costs incurred in regenerating the pine can be substantially minimized. However, there are on occasion problems related to density and spacing in at least some of the seeded stands. Understocking seems to be the most frequent problem, although when seeding and all other conditions are just right, overcrowding can occur. Density adjustments, either by filling in the regeneration gaps or by thinning the overcrowding when it occurs, may be required in seeded stands. Some of this should be controlled by adjusting the intensity of treatments associated with seeding, and the remaining costs of stand tending, if needed, should then be covered by the accrued savings in the costs of seeding versus the costs of planting. As for the problem of seedling clumps on the scarified and seeded scalps when spot cultivators are used, the naturally differentiated assertion of dominance by the pine is the likely solution. In the final analysis, the seeded stands may still prove to have better rooting, better form, and better growth rates than some of their planted counterparts.

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